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Hydration and nutrition knowledge in adolescent swimmers. Does water intake affect urine hydration markers after swimming?

Cesare Altavilla [1], M. Soledad Prats-Moya [2], Pablo Caballero Pérez [3]

[1] *Foods analysis and nutrition group; University of Alicante; Alicante; Spain. ORCID: 0000-0002-7415-4139;*
[2] *Analytical chemistry; nutrition and food science department; University of Alicante; Alicante; Spain. ORCID: 0000-0002-1330-2388;*
[3] *Department of Community Nursing, Preventive Medicine, Public Health and History of Science; University of Alicante; Alicante; Spain. ORCID: 0000-0002-1234-2150; maria.prats@ua.es*

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ABSTRACT:

Little data exists regarding nutritional knowledge and hydration in adolescent swimmers. The aim of this study was to assess the level of nutrition and hydration knowledge and to describe the fluid balance in adolescent swimmers during training. A study was carried out with a cross-sectional descriptive part and a longitudinal part with repeated measurements over five swimming sessions. Eighty-six adolescent swimmers completed a questionnaire to assess their sport nutrition and hydration knowledge. Fluid balance and urine hydration markers were studied during training. Swimmers showed a limited nutrition knowledge (33.26 % ± SD 12.59) and meagre hydration knowledge (28.61 % ± SD 28.59). Females showed lower scores than male swimmers in nutrition and hydration knowledge. Based on urine specific gravity, swimmers started the training close to the euhydrated threshold (1.019 g/mL ± SD 0.008). Although urine specific gravity and urine colour were reduced after the training, there were minimal changes in body mass (-0.12 Kg ± SD 0.31). Sweat loss (2.67 g/min ± SD 3.23) and the net changes in the fluid balance (-0.22 % ± SD 0.59) were low. The poor knowledge in nutrition and hydration encountered in the swimmers can justify the development of a strategy to incorporate nutritional education programmes for this group. Body water deficit from swimming activity seems to be easily replaced with the water intake to maintain hydration. After the training, the urine of swimmers was diluted regardless of their water intake. Dilution of urine did not reflect real hydration state in swimming.

KEY WORDS Swimming practice - Fluid balance - Aquatic sports – Nutrition information - Sweat - Young athletes – Water loss

INTRODUCTION

During adolescence, significant changes prepare a child for adulthood and the nutritional requirements must cover the physical and psychological needs. In developed countries, adolescents usually have bad eating habits. Young people with bad eating habits are more likely to suffer from obesity, fatigue, nutrient deficiencies and poor cognitive skills. Furthermore, it has been well established that diet can have a profound impact on athletic performance and energy recovery [1]. Teenagers often substitute meals with snacks of low nutritional value and they usually consume insufficient amounts of fruit and vegetables [2]. An imbalanced nutrition and lack of nutrition knowledge have been described in athletes before [3–5]. Additionally, young people also show poor knowledge in cooking and food safety practice. It is frequent to find misunderstanding of dietary roles of protein, fat, carbohydrates, the role of vitamins and minerals, carbohydrate loading, glycaemic index [4,6].

Up to now, few studies have been conducted on adolescent swimmers about their nutritional knowledge [7,8]. More specifically, there is no study about hydration knowledge in adolescent swimmers.

Science is doing research on evidence-based strategies to ensure a balance hydration for the general population and specifically for athletes. During exercise, the internal body temperature rises. Sweating is the main mechanism to increase body heat loss. When exercising in a hot environment, the sweating rate can reach as much as 1–2 litres of water loss per hour [9]. Sweat loss could be reduced in the aquatic environment.

The goal of fluid balance should prevent excessive imbalance of body water (± 2% of body weight) and changes in the electrolyte balance. There are some easy techniques to measure changes in hydration state such as measurement of body mass changes [10], bioelectrical impedance [11], and urine indexes [12]. However, each technique has some limitations [11,13,14]. Scientific literature on fluid balance in swimming is poor and predominantly focused on studying adult elite swimmers [15,16]. Few studies have been conducted on adolescent swimmers [17,18]. To our knowledge, there are no studies regarding the effects of different water intake on urine hydration markers in swimming. It seems to be important to provide new data in adolescent swimmers.

The purposes of this study were: to investigate the level of hydration and nutrition knowledge of the adolescent swimmers and to provide new data by analysing the water intake and the fluid balance of adolescent swimmers during training. Furthermore, based on different water intake of the swimmers, fluid balance and urine hydration markers were studied.

METHODS

Participants

This study was divided into two parts: a cross-sectional descriptive part and a longitudinal part with repeated measurements over five sessions of training. The study was carried out between March 2016 and April 2016. A group of 86 adolescent competitive swimmers aged between 11 and 16 years old, was selected. The group was composed of 40 males with mean values of: age 14.06 years old (Standard Deviation: SD 1.34), height 1.67 m (SD 0.09) and weight 55.68 Kg (SD 10.94). There were 46 females with mean values of: age 12.83 years old (SD 1.33), height 1.57 m (SD 0.05) and weight 51.27 (SD 7.24). All swimmers participated voluntarily in the study and their legal guardian signed a written informed consent form. The ethics committee of the University of Alicante granted ethical approval according to the Declaration of Helsinki (1964) and its later amendments or comparable ethical standards.

Procedures

To assess the knowledge of nutrition and hydration, the swimmers completed a questionnaire on nutritional knowledge. The questionnaire used in this study was developed by Zawila [6] and revised to its current Spanish form (with three response options true, false or do not know) by Mariné [19]. To assess hydration knowledge, the questions concerning hydration from 7 to 11 of the questionnaire on nutritional knowledge were analysed separately. The questionnaire was administered to each swimmer by one or more researchers and the guidelines were read to all participants to ensure that the questionnaire was completed appropriately.

Fluid balance was monitored over a five-day period during the afternoon training in an indoor swimming pool. In each session, swimmers swam between 90 and 120 minutes and covered a minimum of 3000 meters. Water temperature, air temperature and humidity were provided by the pool attendant. Water temperature was measured by NSF11061, Deltatrack, Pleasanton, USA. Air temperature and the percentage of humidity were measured by AZ0001, AZ Instruments, Taiwan. All swimmers declared that they had not consumed any fluid retaining or diuretic medications or any supplements in the previous 4 weeks. The swimmers´ coaches agreed to maintain typical routines of work to ensure a standard representation of water intake and fluid balance. Body mass was recorded before and after each training session, while the participants were wearing only their dry swimsuits using a scale (Tanita BH 420MA, Tanita Corporation, Japan). On the first day of the study every participant was provided with a 650 mL bottle of water and they were instructed to drink only from their own bottle and not to modify their drinking habits. Each participant´s bottle of water was weighed immediately before and after each training session. Researchers recorded when a bottle was refilled and took it into consideration for calculating the weight. Each measurement was assessed twice and the relative mean values were used.

Urine samples were collected before and after the training sessions in a container. Water intake and urinary output were weighed with a scale (Terraillon KEA15013FR, Terraillon, France). The swimmers were instructed to collect the urine if they needed to urinate during the training. Swimmers were classified according to the euhydration threshold: urine specific gravity (USG) $\leq$ 1.020 g/ml [20] and urine colour (UCol) $\leq$ 3 [12]. USG was measured with a hydrometer (KLG017, Nahita, USA) meanwhile urine colour was categorized using a urine colour chart [12]. An USG value higher than 1.020 g/ml, or an UCol value $\geq$ 4 was classified as a fluid deficiency (hypohydration).

Data Analysis

For the sport nutritional questionnaire, statistical analyses were performed using logistic regression adjusting for age and sex. Linear regression analysis was used to analyse the percentages of correct, incorrect and "do not know" answers of the sport nutritional knowledge questionnaire. The questions concerning hydration from 7 to 11 of the questionnaire on sport nutritional knowledge were also analysed separately with the same statistical analysis.

For the hydration assessment, mean sweat loss for each swimmer in each session, was estimated using the following formula:

Sweat loss (g/min) = [(Before training body mass (g) – After training body mass (g)) + fluid intake (g) - (urine(g) + faecal output (g))]/min.

Net change in fluid balance (%), for each swimmer and for each session, was calculated using the following formula:

Net change in fluid balance (%) = [(After training body mass (g) - Before training body mass (g))/ Before training body mass (g)] x l00.

The ratio between urinary output and water intake was also calculated, for each swimmer and for each session, using the following formula: Water intake (mL / min) / Urinary output (mL / min).

Water intake, urinary output, ratio between urinary output and water intake, sweat loss, net change in fluid balance, body mass, USG and UCol were presented as mean of the swimming sessions that were carried out. The differences for each swimmer between before and after the training were calculated by averaging the differences of each day.

Swimmers were also divided into two groups based on the cut-off of 2.5 mL / min of water intake. Based on our results, this value is the 50th percentile of water intake of the swimmers.

The changes of the variables studied during the study were calculated based on daily differences between before and after the training. Thus, for each swimmer the changes of the analysed variables are an average of the daily means calculated during the study. Pearson's coefficient of correlation was calculated to determine the correlation between USG and the rest of the hydration markers, and between water intake and the urinary output. A one-way analysis of variance for repeated measurements was used to compare before and after the training means values. Statistical analyses were performed using Statistical Package for the Social Sciences 18.0 software for Window (IBM SPSS Software, Armonk, NY, USA) with statistical significance set at $p \leq 0.05$.

STATISTICAL RESULTS

The results for nutrition and hydration knowledge are shown in Table 1. The adolescent swimmers showed a limited nutritional knowledge. There were significant differences in the nutritional knowledge depending on age and sex. The 14-16 age group showed a significant higher percentage of correct answers ($p \leq 0.01$) as compared to the 11-13 age group and the "don't know" answers were significantly lower for the 14-16 age group ($p \leq 0.01$). Female swimmers showed a significant lower nutritional knowledge than male swimmers ($p \leq 0.05$).

All swimmers showed meagre hydration knowledge. It was revealed that they had a higher percentage of wrong answers together with a lower percentage of "don't know" answers as compared to the answers related to the sport nutrition knowledge questionnaire. The female swimmers showed lower hydration knowledge than the male swimmers and in addition there were significant higher percentage of "don't know" answers than the male swimmers ($p \leq 0.05$). Water temperatures, air temperature and percentage of humidity during training remained relatively consistent between days. The mean water temperature was 29.04 °C ± SD 0.10, the mean air temperature was 30.32 °C ± SD 0.12 and the mean percentage for humidity was 60.91 ± SD 1.52.

The results on hydration assessment are shown in Table 2. Sweat loss and percentage of net changes in fluid balance were minimal during the training. The swimmers showed losses of fluid well below 2% of their body mass and their water intake was very close to the amount of fluid they lost during the training. Female and male swimmers showed similar water intake, urinary output, sweat loss and the ratio between urinary output and water intake. Female swimmers demonstrated the best net change in fluid balance ($p \leq 0.01$) with the least variation in body weight. Females showed a water intake very close to their fluid loss by exercise, urinary output and sweat loss. A significantly low correlation was present between water intake and urinary output (r2 0.09; p 0.004). There was significant difference in net change in fluid balance (%) between sexes (p 0.01). The males showed body mass loss after the training higher than females ($p \leq 0.05$).

Table 1.
Results of the questionnaire on nutritional knowledge and questions concerning hydration knowledge in adolescent swimmers (n 86).

NUTRITIONAL KNOWLEDGE QUESTIONNAIRE				
	Mean (SD) (95%CI)	**Age Coef. (Sig.) (95%CI)**	**Sex Coef. (Sig.) (95%CI)**	**Age/Sex Coef. (Sig.) (95%CI)**
% correct answer	33.26% (12.59)	7.68 (0.01**)	-5.94 (0.04*)	0.76 (0.89)
	(30.38, 36.14)	(2.22, 13.13)	(-11.48, -0.39)	(-10.44,11.99)
% wrong answer	38.67% (11.13)	-3.69 (0.34)	-2.22 (0.58)	3.89 (0.48)
	(36.13, 41.21)	(-12.14, 4.77)	(-10.23, 5.80)	(-7.04, 14.8)
% don't know	28.07% (14.14)	-7.89 (0.01**)	8.57 (0.07)	-4.65 (0.39)
	(24.84, 31.30)	(-14.13, -1.64)	(-1.00, 18.13)	(-17.69, 8.40)

HYDRATION KNOWLEDGE (questions from 7 to 11 in nutritional knowledge questionnaire)				
	Mean (SD) (95%CI)	**Age Coef. (Sig.) (95%CI)**	**Sex Coef. (Sig.) (95%CI)**	**Age/Sex Coef. (Sig.) (95%CI)**
% correct answer	28.61% (28.59)	4.52 (0.66)	-11.67 (0.23)	7.24 (0.59)
	(22.20, 35.01)	(-15.88, 24.93)	(-31.02, 7.69)	(-19.47, 33,95)
% wrong answer	52.66% (33.00)	-3.57 (0.77)	-0.52 (0.96)	-1.50 (0.93)
	(45.27, 60.05)	(-27.79, 20.64)	(-23.48, 22.44)	(-33.18, 30.18)
% don't know	18.73% (19.03)	-0.95 (0.32)	10.32 (0.02*)	-5.74 (0.24)
	(14.45, 22.99)	(-14.31, 12.40)	(1.93, 18.70)	(-23.22, 11.74)

*Coefficients of the linear regression and their confidence interval are shown for age, for sex and interaction among them were calculated. Coef: Coefficient of linear regression, SD: Standard deviation, Sig.: Signification; * $p \leq 0.05$, ** $p \leq 0.01$, 95% CI: 95% confidence interval. Basis line: Boys 11 - 13 age group.*

Furthermore, based on USG and UCol analysis, all the urine samples analysed after the training showed a slight dilution ($p \leq 0.01$). Hydration assessment based on USG showed that the swimmers started their swimming training close to the euhydrated threshold. It was calculated that 46.3% of the swimmers started the training euhydrated. Meanwhile, UCol assessment showed that the swimmers started slightly hypohydrated. There was no difference in urine markers between sexes, males and females that showed lower value after the training than before the training. In USG analysis, there were no differences between male and female swimmers and they reached significant differences after the training. UCol analysis showed low values after the training for males and females, but only the female swimmers reached significant differences after the training ($p \leq 0.05$). A significant moderate correlation ($r2$ 0.55; $p \leq 0.005$) was present between USG and UCol, whereas no correlations were found between the USG and the rest of the hydration markers.

There were 41 swimmers who drank more than 2.5 mL / min of water and 45 swimmers who drank less than 2.5 mL / min of water. The swimmers of the group with higher water intake showed significantly higher urinary output than the ones with lower water intake ($p \leq 0.001$). Furthermore, the swimmers who drank more than 2.5 mL / min of water showed a greater ratio between urinary output and water intake ($p = 0.04$). The swimmers who drank less than 2.5 mL / min of water showed an almost 8-times higher ratio between urinary output and water intake than the ones who drank above the cut-off.

As expected, based on the cut-off at 2.5 mL / min of water intake there were significant differences between the groups in the percentage of net changes in fluid balance ($p \leq 0.01$) and body mass after the training ($p \leq 0.02$). The group of swimmers who drank more than 2.5 mL / min showed minimal changes in the percentage for net fluid balance and body mass after the training. After the training, the swimmers who drank more than 2.5 mL / min of water showed a greater fluid balance based on USG analysis ($p \leq 0.05$), but it was revealed that swimmers with lower water intake showed the same trend in USG analysis, although the USG values did not reach statistical significance (p 0.056). In fact, based on the cut-off at 2.5 mL / min of water intake there was no statistically significant difference in USG between the groups (Table 2). There was no difference in UCol after training based on the cut-off value of 2.5 mL / min of water intake. All the urine samples collected after the training appeared diluted with a paler colour. The USG and UCol analysis showed the same trend to dilution regardless of the amount of water intake.

DISCUSSION

Dietary habits are closely correlated with modernization, urbanization, and socioeconomic development. Consistent with the present study, a moderate or poor nutritional knowledge has been reported in young athletes [8,21]. Unfortunately, there is no nutrition education at schools or swimming clubs. Dietary westernization and lack of nutritional knowledge seems to be particularly evident among the younger generations. Dietary westernization with easy access to ultra-processed food and lack of nutrition education could explain a poor nutritional knowledge of the adolescent swimmers. Nevertheless, our results may indicate that sport activity leads to a greater level of nutritional knowledge than in people who do not engage in physical activity [22].

Results showed that the nutritional knowledge score increased as the age group increased and the score for the male swimmers was higher than the female ones. Previous studies have shown that women, especially adolescent ones, have a higher prevalence of eating disorders than men [23], although swimming is not considered a high-risk sport regarding eating disorders, nutritional education should not be underestimated. Lack of or poor nutritional knowledge are detrimental in adolescent swimmers and could potentially have negative effects on swimmer performance and health. Results highlight the need to plan a strategy for implementing proper nutritional education programmes for adolescent swimmers. These programmes could include cooking classes to provide basic knowledge on cooking techniques and ingredients [24] and should not be limited to adolescents but also include parents and schools. A recent study has shown that nutritional education appears to be an effective resource to improve nutritional habits in adolescent swimmers [7].

The lack of hydration knowledge in young swimmers seems to be at the same level as the nutritional knowledge and does not seem to have any relationship with the water intake, which was adequate throughout the swimming sessions.

Hydration assessment based on USG showed that the swimmers started their training with the hydration level close to the euhydration threshold proposed by the American College of Sports [20]. Whereas in a recent study the adolescent swimmers began the training slightly dehydrated [17]. Taking into account that hydration stress is different in each sport and it has a great individual variability, hydration threshold could be adjusted in accordance with the range proposed by Armstrong [12]. In fact, if we use the range proposed by Armstrong, this different classification of the hydration state between our study and Adams´ study disappears.

A limitation of the work was that it was impossible to collect the swimmers' first urine sample of the day, each morning of the entire period of the study. However previous studies showed that hydration state before the training is similar to the morning one [25,26].

Results, according to previous studies [15,27], confirm that swimmers, as a response to training, have a lower water intake, a lower sweat loss and minimal changes in net fluid balance and body mass if compared to land sports. Minimal water intake and minimal sweat loss could be explained by different thermoregulatory stress of the swimmers because they have more opportunities to dissipate heat in an aquatic environment [28]. Results confirm what was revealed in previous studies that described similar low fluid intake and minimal changes in body mass in adolescent swimmers [17,26].

In a previous study, female swimmers demonstrated a greater water intake than males [26], but in our study the data is not statistically significant. However, in comparison to males, female swimmers showed a slightly higher water intake, a slightly lower urinary output, a slightly lower sweat loss and lower body mass loss. These imply that in our study female swimmers showed a greater percentage for the net change in fluid balance than the males. Based on our results and previous studies [17,25], swimmers have different hydration needs if compared to land sports.

Table 2.
Hydration assessment in adolescent swimmers (n. 86) with the differences in body mass and urine markers between before and after the training.

	Mean (SD)	Male (SD)	Female (SD)	Sig.	Water intake < 2.5 ml/min Mean (SD)	Water intake > 2.5 ml/min Mean (SD)	Sig.
Water intake (ml/min)	2.94	2.75	3.08	0.44	1.41	4.33	0.001
	(1.97)	(1.64)	(2.24)		(0.79)	(1.66)	
Urinary output (ml/min)	1.48	1.75	1.28	0.15	1.04	1.88	0.001
	(1.45)	(1.50)	(1.40)		(1.19)	(1.568)	
Urinary output/ Water intake	2.19	3.41	1.38	0.27	4.04	0.55	0.04
	(7.98)	(11.79)	(2.98)		(11.40)	(0.64)	
Sweat loss (g / min)	2.67	3.13	2.17	0.19	2.36	2.94	0.40
	(3.23)	(3.52)	(3.04)		(2.83)	(3.56)	
Net change in fluid balance (%)	-0.22	-0.38	-0.06	0.01	-0.40	-0.05	0.01
	(0.59)	(0.53)	(0.61)		(0.54)	(0.58)	
Body mass before training (kg)	53.31	55.68	51.27	0.04	50.11	56.23	0.002
	(9.36)	(10.94)	(7.24)		(8.03)	(9.60)	
Body mass after training (kg)	53.19	55.46	51.23	0.05	49.90	56.20	0.001
	(9.31)	(10.89)	(7.21)		(7.93)	(9.54)	
Dif.	-0.12**	-0.22*	-0.05	0.01	-0.21*	-0.04*	0.02
	(0.31)	(0.31)	(0.30)		(0.28)	(0.33)	
TBW before training (%)	59.44	61.90	56.99	0.001	60.12	58.81	0.27
	(5.52)	(5.17)	(4.82)		(4.64)	(6.20)	
TBW after training (%)	58.27	60.60	55.99	0.001	58.99	57.62	0.42
	(5.21)	(4.99)	(4.47)		(4.39)	(5.83)	
Dif.	-1.16**	-1.30*	-1.00*	0.04	-1.12*	-1.19*	0.62
	(0.63)	(0.72)	(0.53)		(0.56)	(0.69)	
USG (g/ml) before training	1.019	1.018	1.019	0.55	1.021	1.016	0.02
	(0.008)	(0.009)	(0.007)		(0.007)	(0.008)	
USG (g/ml) after training	1.012	1.011	1.012	0.88	1.013	1.010	0.15
	(0.008)	(0.008)	(0.008)		(0.008)	(0.007)	
Dif.	-0.006**	-0.005*	-0.007*	0.75	-0.005	-0.007*	0.36
	(0.008)	(0.008)	(0.008)		(0.007)	(0.008)	
UCol before training	4.18	3.96	4.27	0.52	4.64	3.84	0.08
	(1.56)	(1.81)	(1.41)		(1.60)	(1.46)	
UCol after training	3.33	3.44	3.18	0.30	3.53	3.16	0.16
	(1.13)	(1.10)	(1.07)		(1.17)	(1.07)	
Dif.	-0.89**	-0.64	-1.05*	0.47	-0.85	-0.91	0.90
	(1.58)	(1.60)	(1.61)		(1.56)	(1.62)	

*Values are expressed as mean with standard deviation (SD); Sig. Signification, *: $p \leq 0.05$; **: $p \leq 0.01$, USG: Urine specific gravity, UCol: Urine colour. Dif.: Difference between before and after the training.*

A possible explanation might be that for the maintenance of the hydration status, the physiologic response in swimming combines refinedly the temperature of water, the stressors associated with exercise and the impact of hydrostatic pressure.

There are no specific hydration guidelines for aquatic sports and the coaches do not have any official advice to manage hydration with their swimmers. It is not recommended for athletes to drink an amount of water that is more than any weight loss that they may have experienced during training. Some informative articles have outlined recommended fluid intakes for swimmers during training [29,30]. New data provided in this study, together with the lack of evidence of any significant negative effects of a low fluid intake in swimming may indicate that, in adolescent swimmers, it is not necessary to encourage more than 500 ml of fluid intake for a routine swimming session of about 2 hours. Furthermore, other modifying factors could affect the hydration state positively, such as skin permeability [31] and swallowing water when training in the swimming pool [15]. Consequently, the present study suggests that hydration should be considered a mild problem in swimming.

Once the swimming session is finished and the swimming physiologic response is over, we suggest drinking water in order to replenish fluids. The thirst mechanism will allow for adequate fluid intake, so they meet their hydration needs. Thus, the present study suggests that water should be considered a good, cheap and reliable source of liquid in adolescent swimmers during swimming training.

The results of the ratio between urinary output and water intake can be explained by the statistic sensibility of the ratio, whereas some swimmers showed a high urinary output and very low or no water intake. Interestingly, the results of the ratio between urinary output and water intake combined to the urinary markers data show that swimming increases hypotonic urinary output. Furthermore, the analysis of the data with the cut-off at 2.5 mL / min showed a urinary stimulus also in swimmers with a lower water intake, who showed the higher ratio between urinary output and water intake. Some studies have reported that immersion in water increases diuresis and has particular effects on fluid and electrolyte metabolism and circulation [32,33]. Consistent with the present study, in young swimmers it has been reported that urine concentration reduced as a response to swimming training [17,25]. Our study has shown the reduction in USG and UCol after the swimming training and at the same time has displayed that different water intake did not affect urine hydration markers. Thus, to assess hydration in swimming, urine hydration markers do not seem to be reliable methods. The dilution of urine after the training did not reflect hydration state, because the aquatic environment plays as a modifying factor. Specific studies need to be performed to reveal underlying physiological mechanisms involved in the dilution of urine as a response to the swimming training. Taking into account all the information given in this study, a practical alternative for coaches to estimating the hydration state of the swimmers can be a measurement of body mass change after training. The information displayed in the present study could be useful for coaches, swimmers and leisure swimmers.

In conclusion, limited knowledge of hydration and nutrition could make a strategy to incorporate nutritional education programmes in adolescent swimmers necessary. The adolescent swimmers started their afternoon training euhydrated. During the training, fluid loss seems to be easily replaced through water intake. To assess hydration in swimming, urine hydration markers do not seem to be reliable methods. It would be advisable to develop some specific hydration recommendations for swimming and other aquatic sports.

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